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Experimental Results of the Active Deflection of a Beam from a Kicker System

Y. J. Chen
G. Caporaso
J. Weir

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Experimental results of the active deflection of a beam from a kicker system *

Y. J. (Judy) Chen, G. Caporaso, J. Weir
Lawrence Livermore National Laboratory, Livermore, CA 94550 USA

Abstract

A high current kicker has been designed and tested on the ETA-II beam line. A bias dipole which surrounds the kicker acts to deflect the beam in the DC mode. High voltage pulsers (10kV) with fast rise times (10ns.) are connected to the internal strip lines of the kicker. They are used to manipulate beams dynamically.

Camera photos which show the switching of the beam from one position to another will be presented. Beam bug measurements of beam-induced as well as active steering will be shown. These will be compared with theoretical predictions.

1 INTRODUCTION

Recently there has been considerable interest in providing advanced flash x-ray radiography capability for stockpile stewardship[1][2]. A multi-axis capability is required in order to produce a tomographic reconstruction of an imploding assembly. It would be very economical to produce many lines of sight using a single high current electron accelerator if a kicker could be used to axially section a relatively long beam pulse into short pieces which could be directed to different beam lines.

The kicker for this application must be able to handle continuous kilo-ampere beams with great precision and high speed. Switching times of order 10 ns are required in order to make maximum use of the available beam charge. In addition, beam induced fields arise in the kicker and cause additional deflections which must be compensated for by modifying the external pulser voltage waveform.

The idea for this kicker grew out of work done on a "fast corrector coil" (FCC) that was deployed on the Advanced Test Accelerator [3]. The FCC consisted of four rods inside a beam pipe. Each rod was coupled to its own pulser. The FCC could steer a beam in both the vertical and horizontal planes simultaneously.

In order to improve field quality the rods were replaced by curved strip line electrodes approximating a cylindrical boundary as shown in Fig. 1. The resulting structure strongly resembles a strip line beam position monitor that is in wide use in the high energy accelerator community [6]. These kickers are to be used to handle continuous relativistic electron beams of at least several kilo-amperes so that wake fields in the kicker are significant even for a single passage of the beam. The wake fields for structures of this type are strong enough to significantly steer the beam. The input condition on the beam centroid is amplified as a function of beam current [2] for both a passive and kicked mode of operation. The field quality of the shaped electrodes improves field quality but residual higher order moments still exist. The strongest field after the dipole moment is the sextupole moment. The nonlinearity of a sextupole field can shape the beam into a triangle and introduce a small amount of emittance growth [4].

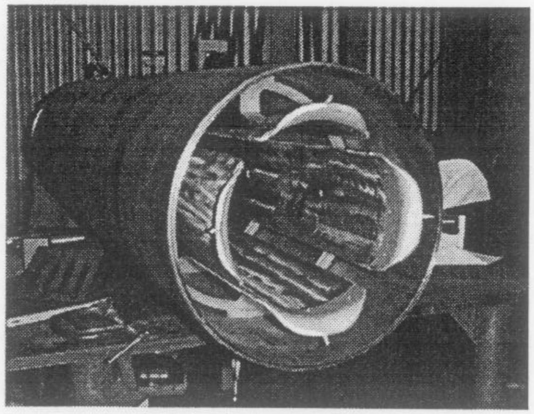

Figure 1: Photo of kicker cross-section which shows kicker plates

2 DESCRIPTION OF EXPERIMENT

The kicker experiment, which comprises high voltage pulsers and the kicker itself with a bias dipole magnet wound around the outside, sits in the transport section of a linear induction accelerator (Fig. 2). A complete system would also include a septum magnet downstream of the kicker. It is the only active component in that section. Experiments to test the system have been and are still being conducted on the Experimental Test Accelerator - II (ETA-II) at the Lawrence Livermore National Laboratory. Two existing pulsers can provide ± 10kV into a 50Ω load with a 10-90% risetime of 10 nsecs. The pulser is shown in Fig. 3.

Two different beam line configurations were used. The original layout proved to be inadequate for the set of beam-induced steering experiments. Two resistive wall monitors (know locally as beam bugs) upstream of the kicker were needed to measure input displacement and angle [5]. In fig. 4a, these were labeled BBT08 and BBT09. However, a large focusing magnet, C4A, resided between the two and was necessary to transport the beam to the output of the kicker. It was quickly realized that incorporation of the C4A in the analysis meant the assumption that the magnet was perfectly aligned. A new beam line was designed such that two beam bugs can be placed upstream of the kicker

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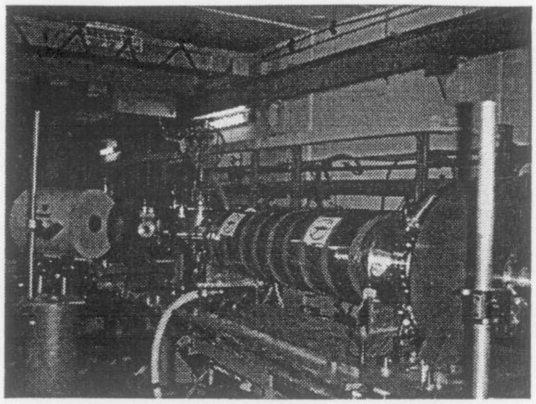


Figure 2: Photo of kicker on ETA-II beam line. White cables (unconnected in this picture) connect pulsers to kicker. Red tape holds bias dipole magnet windings to outer shell of kicker.

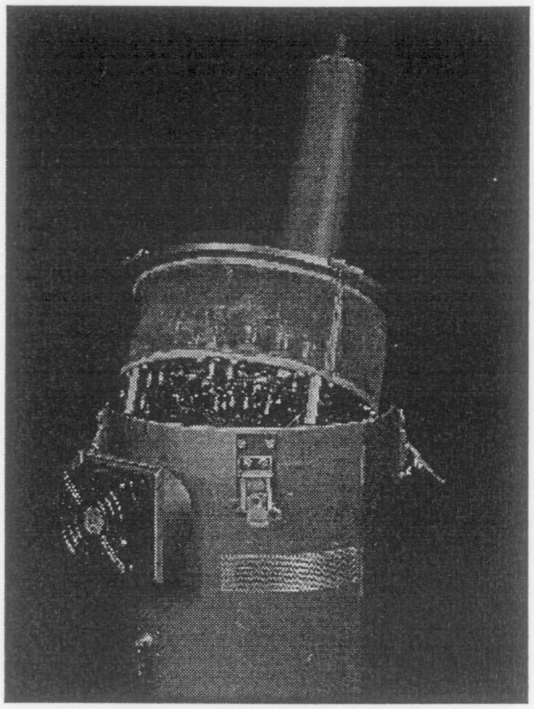


Figure 3: Kicker pulser.

without a magnet between them, as shown in fig. 4b. The spacing between the input bugs must be comparable to the length of the kicker to minimize measurement error in angle.

The first set of results shows that the predicted amplification due to beam-induced steering in a passive kicker matches well with experimental data. These cases were all taken at I_b=1700A where amplification in initial offset is 1.47 and initial angle is 1.08. There is a small background magnetic field that points in both the x and y direction that is folded into the data analysis. The magnetic field pointed in the $-y$ and $-x$ directions (defined by propagation of the beam in the $+z$ direction) with magnitudes of .3-.6G and

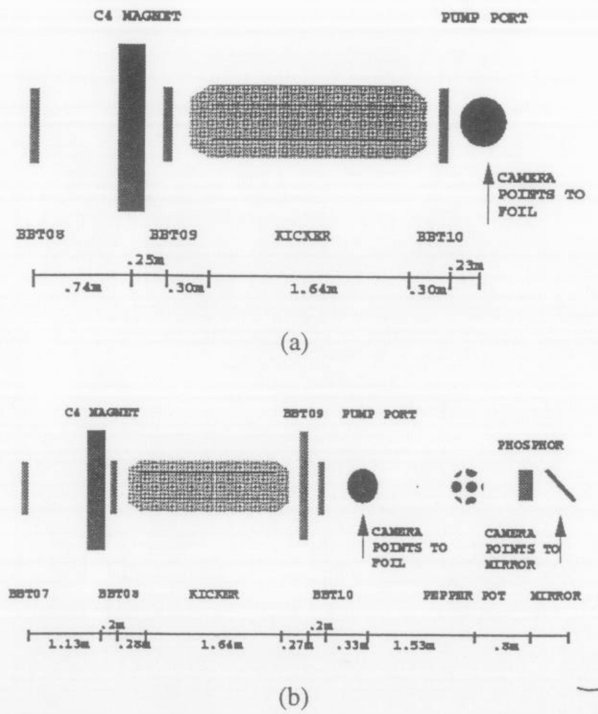


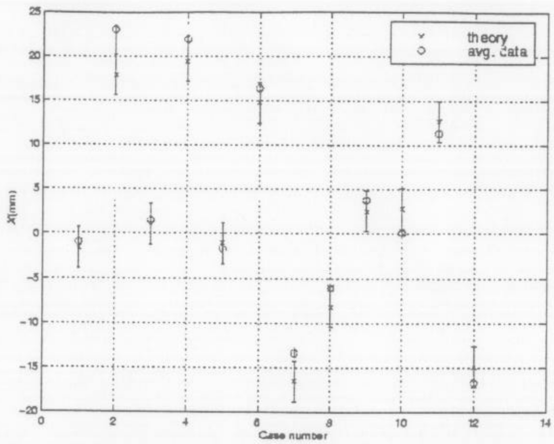
Figure 4: a) Old beam line layout. b) New beam line layout.

.1-.3G respectively. This added an error in beam steering in the $-y$ and $+x$ direction. Fig. 5 shows time-averaged location of the beam at BBT10 for both theoretical projection and actual data for various current values. The error bars on the theory values stems from an assumption that beam bugs have a $\pm$.7mm error. This implies that at BBT10, the error should be $\pm(1.4\text{mm}\times 2.41\text{m}/1.33\text{m}+.7\text{mm}) \approx \pm 3.2$mm [5]. The error bars on the beam bug data include an additional contribution due to the inherent nonlinearity of beam bugs for off-axis measurements. The data are time-averaged over a 40nsec. window.

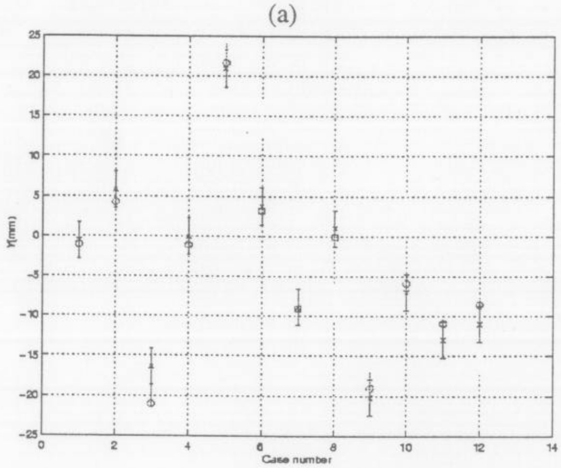
Case 1 was the zero case where the beam entered the kicker on-axis with little to no angle. Cases 2 to 5 were different combinations of initial offsets in x and y, again with no angle. In cases 6 to 9, the beam is steered into the kicker close to axis but with a large angle. Cases 10-12 is another set similar to cases 2 to 5. These sets of data were taken on three different days.

Fig.6 shows the amplification of bias dipole magnet steering as a function of I_b. This data was collected on the old beam line configuration. The kick due to the magnet is normalized to the predicted steering given no beam-induced effect (setting $I_b = 0$). Here we are trying to trace an amplification factor that at the maximum is only 12% as shown in the last data point in figure 6. Although the error bars are large, the general trend fits well with theory.

A series of tests were conducted using the pulsers to kick the beam. Fig. 7 shows a TV image of a 200nsec. time slice of an electron beam at I_b=1200A hitting a quartz foil (see Fig. 4a). The total beam pulse length is only 70nsec. so the camera captured the electron beam as it was kicked from



(a)



(b)

Figure 5: a) Time-averaged x displacement at output of kicker (at BBT10) and b) y displacement show amplification is a function of beam current.

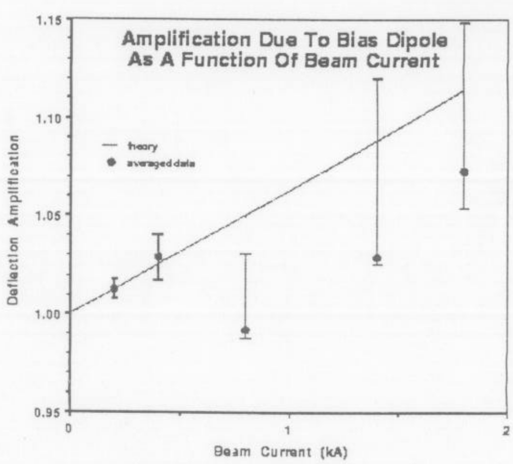


Figure 6: x displacement at BBT09 (old beam line) due to dipole magnet

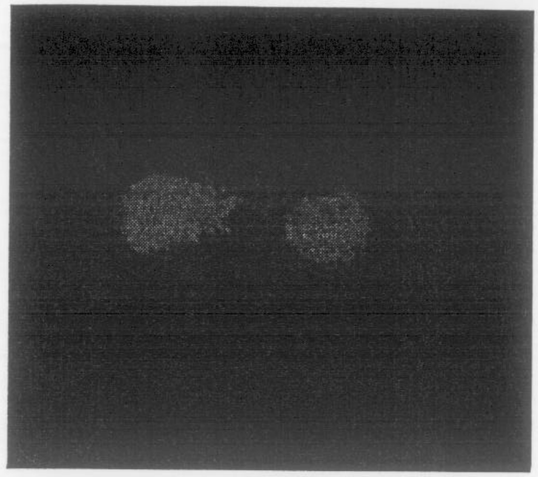


Figure 7: TV camera downstream of kicker which captured the beam as it deflected from one side to the other.

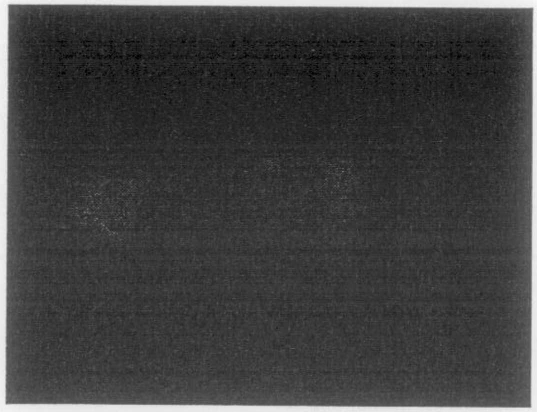


Figure 8: TV camera downstream of kicker which captured a triangularly shaped beam shaped by the sextupole moment inherent in the fields due to the stripline voltages [4].

one position to the other. Fig. 7 shows a beam kicked with V_p=9kV and at an estimated energy of 6.3MeV. The total displacement at the camera foil is 4cm.

3 ACKNOWLEDGMENTS

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